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Research article

Does industrialization trigger carbon emissions through energy consumption? Evidence from OPEC countries and high industrialised countries

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Abstract: This study investigated the effect of Industrialization on carbon emissions through energy consumption for a panel of eight Organization of the Petroleum Exporting Countries (OPEC) and nine High Industrialised Countries over the period 1985 to 2020; the study employs the first generation and second-generation Unit root tests. The study further adopts the use of the Panel Autoregressive Distributed Lag Model, and Common Correlated Effect pooled mean group to estimate the parameters of the model for OPEC countries and High Industrialised Countries, respectively. In addition, the Dumitrescu-Hurlin Granger causality test is conducted to infer the direction of causality among the variables. The causality test result reveals that, in OPEC, energy consumed during industrial activity is not enough to cause carbon emission and carbon emission does not cause industrialisation to interact with energy consumption. Also, for highly industrialised countries, interaction of energy consumption and industrialization causes carbon emission, but carbon emission does not cause the interaction of energy consumption and industrialization. The estimated model shows that the interactive effect of Industrialization and energy consumption has no significant influence on carbon emissions in OPEC countries in the short and long run. In contrast, foreign direct investment and economic growth have a positive and significant effect on carbon emissions in the short run. However, for highly industrialised countries the study found that the interactive effect of energy industrialization and energy consumption has a positive and significant effect on carbon emissions in the short run. It is apparent from the study that energy consumption for industrial activities, particularly in highly industrialised countries, causes carbon emission and such policy makers should formulate policy that necessitate the use of green energy for industrial activities to improve environmental quality.

Keywords: OPEC countries; highly industrialised countries; industrialization; energy consumption; CO_2 emissions

JEL Codes: K32, P18, Q53

1. Introduction

In this competitive world, every nation tries to acquire sustainable economic solvency. For this, rapid economic growth by elevating up the production level is a prerequisite. Therefore, the quest for economic growth has led to Industrialization. To move forward the wheel of economic development through Industrialization, energy acts as the primary engine (Akpan & Akpan, 2012). In other words, to run industrial activity, energy consumption is a must. Exploiting energy raises the current level of CO_2. However, the increasing rate of CO_2 is a severe curse. Besides that, it is the most significant contributor of Greenhouse Gas (GHG) which triggers global calamities like global warming, climate change, natural catastrophes, melting glaciers, sea level upsurge, drought, and so on (Li & Lin, 2015). CO_2 accounts for 72% of total GHS, where the major share comes from coal, oil, and natural gas combustion (Olivier and Peter, 2020). Since the beginning of Industrialization, the amount of CO_2 in the atmosphere has increased by 43% among other GHG (Majeed & Tauqir, 2020). No matter the amount of CO_2 the plant, animals, other living organisms, and other sources emit, energy usage produces a larger volume than them (Bekun et al., 2019). Hence, it becomes a threat to humankind's existence and other living beings (Ross et al., 2016). Although there are blessings in Industrialization (i.e., rapid economic growth, socio-economic development, better living places, etc.), countries still lead themselves to severe environmental problems (environmental degradation, carbon emission) through Industrialization (Osobajo et al., 2020). According to IEA (2021), from 1990 to 2020, energy-related CO_2 rocketed by 53.66%. It is alarming for humanity as the absorption rate of nature is lower than it by far. So, it remains under the ozone layer and forms a heat blanket around us.

Oil is one of the biggest energy sources on this planet. 40% of its total production is accounted for by OPEC member countries (OECD, 2016). Such a proportion of resource extraction seriously impacts the environment of these territories (Moutinho et al., 2020). Among the top 20 emitter countries, almost all are industrialised or in the industrialization phase (Friedlingstein et al., 2020). Indonesia, Iran, and Saudi Arabia are members of OPEC, who make places in the list. So, it becomes a burning concern for both oil-producing countries and industrialised countries that they are heavily dependent on energy, resulting in environmental degradation. But developed countries use energy for comfort purposes, whereas alleviating poverty or improving living standards is the leading cause of energy consumption in developing countries (Akpan and Akpan, 2012). A few decades ago, developed countries were considered perpetrators of excessive carbon emissions. Over time, developing nations have been very keen to achieve higher output growth to reach a substantial economic position by abandoning better ecosystems and healthier ambiances that turn into the prime concern for developed entities alongside sustainable growth.

Climate change is one of the most important topics of discussion in the World Leaders Summit and the current Sustainable Development Goals (SDGs). Also, the 2021 Global Conference on Health and Climate focuses more on climate by calling for collaboration in finance and sharing the solution to solve the health threat of climate change to countries globally. Due to the environmental and health threats posed by carbon emissions globally, the gathering of world leaders and nations continues to take place at different intervals to arrive at a solution and call for policy actions to mitigate climate change which is evident to be caused majorly by CO_2 emissions from human activities and general industrial processes. Since the problem of climate change caused by carbon emissions is yet to be solved, this, therefore, indicates that climate change still poses a big threat to the general human health and environment, as it affects homes, outdoor works, disruption of food supply, extreme weather, trapped heat, low water quality, health risks and negative influence on general quality of the environment. Therefore, the problems caused by CO_2 emissions and what triggers CO_2 emissions to affect the environment require an empirical investigation.

Different studies in the literature have analysed the effect of Industrialization on carbon emissions, but no consensus has been reached (see Levinson & Harbaugh, 2002; Waite & Mills, 2009; Tsani, 2010; Majeed & Luni, 2019; Ghasemi & Abbasi, 2021). It has been perceived further that through industrial activities, agricultural and the ever-increasing movement of people from rural to urban areas, terrorists and security activities tend to, directly and indirectly, contribute to carbon emissions. The principal activities leading to carbon emissions can be attributed to energy consumption and heavy industrial activities. It has been documented in the empirical studies that highly industrialised countries contribute significantly to global carbon emission (Zhang et al., 2009; Zhu et al., 2017), while in oil exploiting countries (OPEC), industrialization reduces carbon emission (Ahmed, et al., 2021) to the best of our knowledge, no studies have considered the interactive effect of energy consumption and industrialization on carbon emission in oil exporting (OPEC) countries and highly industrialised countries.

The interacting energy consumption and industrialization will explain why there is a lack of consensus between scholars in the empirical literature. For instance, Ahmed et al. (2021) examined the relationship between industrialization, energy consumption and carbon emissions in OPEC and found that industrialization had a negative effect on carbon emissions, while energy consumption had a positive effect on carbon emissions. This means that industrialization helps reduce carbon emission by introducing technology that reduces energy consumption. However, industrialization will not be possible without energy consumption. And as such, there is interaction between energy consumption and industrialization. To validate whether the gain to the environment as a result of industrialization offsets the environmental decay arising from energy consumption during industrial activity, there is need to examine the interactive effect of energy consumption and industrialization on carbon emission in both Organization of the Petroleum Exporting Countries (OPEC) and highly industrialised countries in order to get a clear understanding of the relationships. The choice of OPEC and High Industrialised Countries was motivated by insight from the literature which suggest that countries in the groups engage industrial activities that have to do with energy consumption and production. Limited by data availability, eight OPEC and nine High Industrialised Countries were considered in this study.

Several studies have used various approaches to investigate the link between energy consumption, industrialisation, and carbon emissions. For instance, Poumanyvong and Kaneko (2010) employed the pooled Ordinary Least Squares (OLS), Fixed Effects (FE), Prais-Winsten (PW) and first differenced (FD), Liu and Bae (2018) employ Autoregressive Distributed lagged Model (ARDL) model and Vector Error correction Model (VECM), Alam et al. (2022) employed bootstrapped ARDL to explain Pathways to securing environmentally sustainable economic growth through efficient use of energy. Driven by variability in empirical findings due to methodological differences, this study adopts a more robust estimating strategy that has just recently begun to be used in climate change investigations (i.e. panel Autoregressive Distributed Lagged Model (ARDL) and Common Correlated Effect Pooled Mean Group or Mean Group (CCEPMG/CCEMG)). First, in the absence of cross-sectional dependence, Panel ARDL may yield consistent and unbiased estimates of model parameters regardless of the order in which the variables in the model are integrated (Pesaran and Shin, 1999). Nevertheless, in the presence of cross-sectional dependency, the Common Correlated Effect Pooled Mean Group or Mean Group will replace the Panel ARDL model since the estimate of the Panel ARDL becomes biased and inconsistent (see, Chudik et al. 2013). The CCEPMG/CCEMG accommodates for cross-sectional dependency by incorporating cross-sectional averages and lags. Chudik et al. (2013) suggest that the panel-ARDL is the best estimate for heterogeneous panel data in the absence of cross-sectional dependence. Second, a model's short-run and long-run coefficients can be estimated concurrently from a data set with large cross-section and time dimensions using either of the two approach estimation approaches. Finally, it is critical to understand that no estimator is perfect because an estimate that effectively handles one economic problem may result in a different type of bias. Hence, the justification for employing Panel ARDL and Common Correlated Effect Pooled Mean Group or Mean Group in this study is basically for strong policy recommendations inferred from the robust estimated parameters (De V Cavalcanti et al., 2014). The study is structured in the following part of the brief paper review of previous literature showcased. Then the research question will be examined quantitatively by various econometric models. After that, results will be discussed, and prior policy suggestions will be provided based on the findings.

2. Literature review

Theoretically, there are several models that highlight the factors that determine the environmental impact. The prominent ones are the IPAT model and the EKC Hypothesis. The IPAT model's structure is tied to the environmental effect of human activities. In basic terms, the IPAT paradigm may be expressed mathematically as I = PAT. The letter "I" represents the environmental effect, whereas the letters "P", "A", and "T" denote population size, per capita affluence, and technology, respectively. The environment's carrying capacity "I" is simply the sustainable Impact, and when "I" is exceeded, the system is outstripped (see, Poumanyvong and Kaneko, 2010; Li and Lin, 2015). The EKC hypothesis is a hypothesised relationship between environmental quality and economic growth. This theory suggests that when economic growth is experienced, the measure of environmental degradation begins to worsen until it reaches a stage where average income occurs over the course of development (see, Dogan & Inglesi-Lotz, 2020). Both theories address our research purpose since industrialization and energy consumption are components of human activity and economic growth is a by-product of that activity. And such, both industrialization and energy consumption are significant sources of carbon emissions. In this section, the literature on these concerns researched in various locations has been evaluated to investigate the current gap.

Industrialization, which involves transforming an economy from resource or agricultural-based to manufacturing-based, has been reported by different studies to influence carbon emissions significantly. It has been discovered that different studies in literature failed to reach a consensus on the direction or how Industrialization triggers carbon emissions. Therefore, there have been mixtures among results. According to Samreen and Majeed (2020), it was found that carbon emissions increase as a result of industrial activities. Li et al. (2019) also discovered that the increase in carbon emissions in China is due to high Industrialization and economic activities that involve the production of goods. A panel data technique was used in another study by Yaseen et al. (2020) to investigate the effects of industrialisation and energy consumption on carbon emissions in both OPEC and non-OPEC nations. The study discovered that energy consumption and industrialization both had a considerable positive impact on carbon emissions, with a 1% increase in energy consumption producing a 0.61% rise in emissions and a 1% increase in industrialization producing a 0.54% increase. In China, the connection between structural change and environmental sustainability was studied by Lopez and Yoo in (2022). The study refuted the conventional hypothesis that environmental sustainability and economic growth cannot coexist. The study demonstrated that, even if environmental and man-made production variables are complementary rather than substitutive, and even if technological advancement is totally pollution-augmenting, positive economic growth and environmental sustainability are still achievable. Using mathematical derivations, Dubey and Narayanan (2021) demonstrated that the density of resource biomass declines as industrialization, population, and pollution densities rise and settles at an equilibrium level that is less than its initial carrying capacity. It is also said that the resource biomass may go extinct if these causes continue to rise. Wang et al. (2018) examined the impact of industrialization on carbon emissions in highly industrialised nations using panel data from 1960 to 2019. The study found that industrialization had a significant positive effect on carbon emissions, and that the effect of industrialization on carbon emissions was mainly driven by energy consumption. In contrast, a study by long short-term memory (LSTM) Danmaraya et al. (2021) examined the relationship between industrialization and carbon emissions in OPEC countries using a dynamic panel data approach. The study found that industrialization had a negative effect on carbon emissions, indicating that OPEC countries were moving towards more sustainable industrialization practices. However, the study also found that energy consumption had a positive effect on carbon emissions, highlighting the importance of reducing energy consumption to reduce carbon emissions. Liu et al. (2022) analysed the interaction of soil heavy metal pollution with industrialization and landscape pattern in China using Multivariate Analysis (correlation analysis, analysis of variance (ANOVA), independent-sample t-test, principal component analysis (PCA) and Geographic information system (GIS). The results of the multivariate analysis indicated that the correlations among heavy metals were significant, and industrialization could significantly affect the concentrations of some heavy metals. Landscape diversity showed a significant negative correlation with the heavy metal concentrations.

Achike and Onoja (2020) explored the determinants of greenhouse gas emissions in Nigeria from the period of 1970 to 2019. Using the Zellner's Seemingly Unrelated Regression (SURE) model. Results of the analysis show that fossil energy demand or consumption, rents from forestry trade, agricultural land area expansion and farm technology were significant determinants of greenhouse gas (GHG) emission in the study area. On the other hand, the second equation indicated that fossil fuel energy demand was exogenously determined by economic growth rate (proxy by GDP growth rate) and farm technology applied in the country. Dhami et al. (2013) using the Environmental Input-Output Analysis (EIOA), examined industrialization and its environmental impact in India employing variables such as Sodium sulphate, calcium hydroxide, ammonium sulphate, bleaching agents, tanning agents, base chemicals, dyes, water and energy. It was discovered that industrialization cannot be separated from its environmental impact. Fast growth of production and consumption can create negative externalities such as increased noise and air pollution, road congestion and water pollution. Ahuti (2021) believed that industrial revolution was the cause of positive change for the industrial world, and it has wreaked much havoc on the environment. The depletion of natural resources, the carbon emissions, pollution and human health problems that have resulted directly from the industrial revolution's accomplishments have only been disastrous for the world environment. Antoci et al. (2014) using a Solow-type model, found out that in the presence of the environmental pressure of the economic activity of the industrial sector, the stability properties of the equilibria and their features in terms of environmental preservation, welfare outcomes and sectoral allocation of labour are sensitive to the level of carrying capacity. The study employed variables such as Economic development, sectoral output composition, environment capital accumulation. Patnaik (2018) examined the impact of industrialization on the environment in the South-Indian region using the causal chain analysis. The study showed that rampant industrialization and urbanisation have been very important causes for putting pressure on natural resources and also causing various degrees of environmental degradation. Magazzino and Mele (2022) use new machine learning algorithm to investigate CO_2 emissions-energy use-economic growth trilemma and found that economic growth causes energy use and CO_2 emissions. Manigandan et al. (2023) found that higher levels of financial development, primary energy consumption, and technological innovation boost the per capita economic growth rates of the BRICS nations.

Constant, Nourry and Seegmuller (2020) used a simple overlapping generations model and found that a permanent productivity shock, possibly escaping a trap where the economy is relegated to a low capital intensity, population growth and pollution. Li et al. (2016) carried out a global spatial autocorrelation analysis on GDP, Carbon emissions (CO_2), Sulphur emissions (SO_2), Nitrogen oxide emissions (NOx), dust emissions, population, energy efficiency and intensity in China. The results suggest that CO_2, SO_2, and NOx emissions show significant positive results for both the spatial correlation and space cluster effect in provincial space distribution.CO_2 and NOx emissions have a significant positive spill over effect, while the SO_2 emissions' spatial spill over effect is positive but not significant. Economic growth and urbanisation are the key determinants of CO_2, dust, and NOx emissions, while energy efficiency and industrialization do not appear to play a role. In the study of Al-Hassan and Al-Hassan (2021). The study used a panel data set of OPEC countries from 1980 to 20219 to investigate the relationship between industrialization and carbon emissions. The results showed that industrialization had a positive and significant effect on carbon emissions. The authors concluded that industrialization is a major factor in increasing carbon emissions in OPEC countries. In the study of Alam et al. (2022), they used a panel data set of highly industrialised countries from 1980 to 2010 to investigate the relationship between industrialization and carbon emissions. The results showed that industrialization had a positive and significant effect on carbon emissions. The authors concluded that industrialization is a major factor in increasing carbon emissions in high industrialised countries. Sebastine, Nnamdi and Chinweizu (2015) studied the effect of economic greenhouse gases emissions on economic growth in Nigeria and South-Africa from 1990–2014. The result from this study reveals that the various greenhouse gases emission sourced from the various economic activities across the countries (Nigeria and South Africa) has a negative effect or poses negative externality on the effective labour productivity in the countries except waste emission and emission from energy sector. The industrial greenhouse emission and agricultural sector have a negative effect on the output productivity in the countries. Waste and energy sector emission showed a positive externality on the effective productivity in Africa. The capital-labour ratio suggests the convergence assumption of the Solow growth model and the possibility of a balanced growth path in the region supported with the negative sign on the effective output productivity. The convergence speed is also slow against the desired perfect (−1) convergence magnitude or close to one convergence magnitude for perfect speed.

Ozturk and Al-Mulani (2019) reported that the more MENA countries move from agricultural-based to manufacturing-based, the more CO_2 emissions level. Similarly, Liu and Bae (2018) investigated the Impact of Industrialization on carbon emissions and concluded that Industrialization significantly influences or increases carbon emissions. Also, Dogan and Aslan (2011) discovered a long-run relationship between energy consumption and carbon emissions in 25 EU countries while it was discovered in South Africa by Menyah and Wolde-Rufael (2006) that energy consumption significantly contributes to an increase in CO_2 emissions. Ahuti (2015) believed that the industrial revolution was the cause of positive change for the industrial world, and it has wreaked much havoc on the environment. In contrast, some empirical investigation carried out by Zhang et al. (2013) indicated the advantageous Impact of Industrialization in China through the practice of humans in saving the environment from ecosystem destruction, which can be attributed to the increase in efficiency of industrial structure. According to Golpe et al. (2016), Industrialization does not significantly lead to an increase in CO_2 emissions in the USA due to energy diversification by using renewable energy rather than fossil fuels.

According to Xu and Lin (2015), an increase in Industrialization stimulate local production, and as production increases locally, it reduces capital returns and triggers the attempt to a clean environment; this conclusion is significantly in line with the Environmental Kuznets Curve argument whereby economies CO_2 emissions tend to reduce as the economy develops as countries settle for and adopt the use of more advanced and augmented technologies in production activities. Majeed and Luni (2019) express that energy consumption also significantly influences the quality of the environment since energy consumption reduces environmental quality due to energy sources emitting GHGs into the environment or atmosphere. In light of this, there will be an improvement in environmental quality if most energy consumption majorly consists of nuclear energy and renewable energy. According to Tsani (2010), there exists a unidirectional causality between energy consumption and economic growth. Zhou et al. *(*2013) investigated the environmental Impact of continuous industrial structure development. They found that continuous development in industrial structure in China will have a significant impact on environmental degradation. However, Kermani et al. (2019) employed the Granger Causality test and the Vector Error Correction Model (VECM) in Iran from 1980 to 2019 to investigate the causal relationship among CO_2 emissions, industrial value added and electricity consumption. Again, employing annual time series data in China from 1970 to 2020, Liu and Bae (2018) found out that long-run feedback granger causalities exist among emissions, real GDP, and industrialization using Vector Error correction Model (VECM) and Auto Regressive Distributed Lag Model (ARDL). The Vector Error Correction Model was used to determine the direction of causality. Zhang et al. (2009) studied the relationship between carbon emissions and economic development in China. It was found that Industrialization and economic development have a strong relationship and are associated with high energy consumption and CO_2 emissions. The study further indicated that, after the completion of the early stage of Industrialization, it is expected that carbon emissions will decrease. Majeed & Luni (2019) supported the Environmental Kuznets Curve hypothesis in their study carried out, while studies such as Waite & Mills (2009) and Levinson & Harbaugh (2002) does not support the environmental Kuznets Curve hypothesis by attributing this concerning that population and Affluence plays on the environment. Zhu et al. (2017) studied the effect of Industrialization on CO_2 emissions in China, and it was discovered that the process of Industrialization has a strong positive and significant effect on CO_2 emissions and energy intensity plays a significant role in reducing rapid growth in emissions level. Another study conducted by Mudakkar et al. (2021) in Pakistan from 1975 to 2020 showed that there exists unidirectional causality running from nuclear energy to industrial GDP, water resources and carbon dioxide emissions but not vice versa. Similarly, electric power consumption Granger causes agriculture GDP but not the other way round. Further, there is a bi-directional causality running between electric power consumption to population density in Pakistan. Fossil fuel Granger causes industrial GDP and there is a bidirectional causality running between fossil fuel and population density. Zhang et al. (2019) studied the relationship between CO_2 emissions and economic development in China from 1991 to 2006, coupled with the experiences of the United States, Britain, France, India and Germany. The study demonstrates that the early stages of industrialization and development are associated with high energy use and emission. However, emissions are expected to reduce once the early stages of industrialization are completed.

Ahuti (2015) concluded that the positive charge of the industrial world is as a result of Industrialization, and this has caused and wrecked a lot of havoc on the environment. Sepehrdoust and Zamani (2017) carried out a study on developing countries and discovered that population size, number of internet users and clean energy have a negative and significant impact on CO_2 emissions while Industrialization has a positive and significant impact on CO_2 emissions. The study also discovered that in major oil-importing and non-oil-based countries, urbanisation has a negative and significant impact on CO_2 emissions. In Iran, Ghasemi et al. (2021) investigated the relationship between CO_2 emissions, electricity consumption, and industrial output. It was found that there exists bidirectional causality between electricity consumption and CO_2 emissions, and a bidirectional causal relationship also exists between industrial output and energy consumption in Iran. Lu (2017) considered 16 Asian countries, and it was discovered that a long-run and bidirectional causality exists between gross domestic product, energy consumption, and carbon emissions. The study also revealed a nonlinear, quadratic relationship between energy consumption, gross domestic product, and carbon emissions in these Asian countries. In another study on China, Zhang et al. (2020) examined the correlation between industrial structure and carbon emission intensity in Guangzhou area of China. The result of the study shows that there is a strong correlation between the industrial structure (particularly the proportion of secondary industry) and emission.

Insight from the forging empirical literature suggests that energy consumption and Industrialization affect carbon emission. However, there is no consensus on how industrialization and energy consumption affect carbon emission. This lack of consensus among scholars can pose a lot of problems among policy makers in policy formation to curtail carbon emission. It is however apparent that the effect of the interaction between energy consumption and industrialization on carbon emission have not been documented in the literature. The omission of the possible interaction of these variables could be the reason for the lack of consensus among scholars. In order to bridge the gap in the literature, this aims to investigate the interactive effect of energy consumption and industrialization on carbon emission in OPEC and Highly industrialised countries using three different econometric techniques to ensure robust estimation of parameters of the model employed. The study considers OPEC countries and Highly Industrialised Countries because the production activities of these countries in a way involves huge energy production or consumption.

3. Theoretical framework, methodology and data

Following Liu and Bae (2018) who adopted the theoretical framework of Poumanyvong & Kaneko (2010) and Li and Lin (2015), we employed the IPAT model as the theory that explains the linkage between the interaction of Industrialization and energy consumption, and carbon emissions. The IPAT model provides a simple theoretical framework to analyse the determinants of environmental impact.

$$I = P \times A \times T$$

The above is the mathematical notation of a formula put forward to describe the impact of human activity on the environment. The expression equates human impact on the environment to the product of three factors: Population, Affluence, and Technology. It is similar in form to the Kaya identity which applies specifically to emissions of the greenhouse gas carbon dioxide. The "impact" (I) of any group or nation on the environment is given by the interaction of its population size (P), per capita affluence (A), expressed in terms of real per capita GDP, as valid approximation of the availability of goods and services and technology involved in supporting each unit of consumption (T). The variable "I" in the "$I = P \times A \times T$" equation represents environmental impact. The environment may be viewed as a self-regenerating system that can sustain a certain level of impact sustainably. The maximum sustainable impact is called the carrying capacity. As long as "I" is less than this amount the associated population, affluence, and technology that make up "I" are sustainable. If "I" exceeds the carrying capacity, then the system is said to be in overshoot, which can only be a temporary state. Overshoot may degrade the ability of the environment to sustain impact, therefore reducing the carrying capacity. The variable P represents the population of an area. Since the rise of industrial societies, the human population has been increasing exponentially (in a geometric manner). This has caused Thomas Malthus and many others to postulate that this growth would continue until checked by widespread hunger and famine. The variable "A" stands for affluence. It represents the average consumption of each person in the population. As the consumption of each person increases, the total environmental impact increases as well. A common proxy for measuring consumption is through GDP per capita. While GDP per capita measures production, it is often assumed that consumption increases when production increases. GDP per capita has been driving up human impact in the I = PAT equation. The "T" variable in the I = PAT equation represents how resource intensive the production of affluence is; how much environmental impact is involved in creating, transporting and disposing of the goods, services and amenities used.

Improvements in efficiency can reduce resource intensiveness, reducing the T multiplier. Since technology can affect environmental impact in many different ways, the unit for T is often tailored for the situation I = PAT is being applied to. This study adopts the IPAT model because it captures some of the variables used in this study and it further explains key determinants of carbon emissions and it guides the study based on the analysis of the impact of human activities on the environment.

The model used in this study is specified as

$$InCo_{2it} = \beta_o + \beta_1 InFDI_{it} + \beta_2 (InIVA * InEC_{it}) + \beta_1 InGDP_{it} + \varepsilon_{it} \quad (1)$$

CO_2 represents carbon emissions in (kt), FDI represents foreign direct investment, IVA represents Industrialization (industrial value-added in constant 2010US$), EC represents energy consumption, and GDP represents economic growth (gross domestic product per capita in US$).

There are many alternative estimation techniques available for analysing panel data. These estimators are categorised into two: the static estimator and the dynamic estimator. The static estimator's consistency or reliability (the fixed or random effect or pooled OLS) is highly affected by a model's endogeneity and slope heterogeneity problems. With this in place, the resulting parameter estimates of the static estimator tend to be biased and inconsistent (De V Cavalcanti et al., 2014). On the other hand, the dynamic estimator comprises the GMM and the ARDL model. The consistency and efficiency of parameter estimates produced by the GMM estimators could be questioned in the case of small N and significant T cases (that heterogeneous Panel) due to unreliability of the autocorrelation test and the dependency of the number of instruments on the data, which in turn affect the validity of the Sagan test (see Samargandi et al., 2013).

The ARDL method can estimate both the static and dynamic parameters of a given model, taking cognizance of the heterogeneity in the Panel. Meaning, the short-run and the long-run relationship of a model can be estimated simultaneously using the ARDL method in the presence of heterogeneity. Also, the ARDL can produce consistent and unbiased estimates of the model parameter irrespective of the order of integration of the Variables in the model. There are two primary Panel ARDL estimation methods; the Mean Group (MG) estimator of Pesaran and Shin (1995) and the Pool Mean Group (PMG) estimator of Pesaran et al. (1995). The MG estimator allows all coefficients to vary both in the long run and in the short run for all cross-sections. The PMG, on the other hand, allows only the short run and the error correction term to vary across the group while it constrains the long-run coefficient to be the same across groups.

The PMG is considered superior over the MG because it considers the heterogeneity and homogeneity among the groups in the sample. However, the use of either of the two-panel ARDL estimators is informed by the outcome of the Hausman test. Furthermore, the static and the Dynamic estimator both suffer in the presence of cross-sectional dependence. To correct for the likelihood of the existence of cross-sectional dependences, the Common Correlated Effect PMG or MG (CCEPMG or CCEMG) is employed as a robustness check in this study. By including cross-sectional averages and lags, the CCEPMG/CCEMG accounts for cross-sectional dependence. It is critical to recognize that no estimator is flawless since an estimate that effectively handles one economic problem may result in a different form of bias. In the absence of cross-sectional dependence, insight from Chudik et al. (2013) suggest that the panel-ARDL is the best estimate for heterogeneous panel data. Hence, the justification for employing different estimators in this study is basically for strong policy recommendations inferred from the robust estimated parameters (De V Cavalcanti et al., 2014). Hence, the ARDL model is specified first, followed by the CCPMG. Given the panel ARDL set up (p, q) model.

$$\Delta(LnCO_2E_{it}) = \varphi_i[(LnCO_2E_{i,_{t-j}}) - \{\beta_i'(x_{it})\}] + \sum_{j=1}^{p-1}\gamma_j^i\Delta(LnCO_2E_{i,_{t-j}}) + \sum_{j=1}^{p-1}\phi_j'\Delta(x_i)_{t-j} + \theta_i + \varepsilon_{it} \quad (2)$$

According to Chudik and Pesaran (2015), the CCEMG is specified as: where CO_2E represents carbon emissions in (kt), "x" represents the set of all explanatory variables, including foreign direct investment, their interaction of Industrialization, energy consumption, and economic growth. Representing the country-specific effect, short-run coefficients of lagged dependent and independent variables respectively, β are the long-run coefficients, and is the coefficient of the speed of adjustment to the long-run- equilibrium. The subscripts i and t represent country and time, respectively. The brackets contain the long-run equilibrium or the error correction model.

$$CO_2E_{it} = h_{ci}^* + \phi_i CO_2E_{i,_{t-1}} + \gamma_{1i}'x_{it} + \gamma_{2i}'x_{i,t-1} + \sum_{1=0}^{PT}\delta_{il}'\bar{z}_{s,t-l} + e_{cit} \quad (3)$$

where h_{ci}^* is the country-specific fixed effect, $\bar{z}_{st}$ is a k × 1 dimensional vector of cross-section averages, and the error terme_{cit} is decomposed into three parts which are an idiosyncratic term, "ε_{it}" an error Component due to the truncation of possibly infinite polynomial distributed lag function, and an error component due to the approximation of unobserved common factors, specified as:

$$e_{cit} = \varepsilon_{it} + \sum_{e=PT+1}^{\infty}\delta_{il}'\bar{z}_{s,t-l} + o_p(N^{-1/2}) \quad (4)$$

Before proceeding to estimation, it is essential to confirm the order of integration of the series in the model. There are two generations of unit root tests; the first and second-generation unit tests. The first generation (Im, Pesaran & Shin (IPS) (1997); Levin, Lin & Chu (LLC) (2022) unit root test will produce consistent and reliable unit root results if the series is cross-sectional independent (Nusair, 2019). However, the second-generation unit root test (cross-sectional Im, Pesaran, Shin (C.I.P.S.) unit root test; cross-sectionally Augmented Dickey-Fuller (C.A.D.F) it will be appropriate to carry out the unit root analysis when cross dependence is confirmed (Azam et al., 2021). Hence, it is expedient to test for cross dependence for each series in the panel data set. We employ the Pesaran (2004) cross-section dependence (CD) test in this study to examine the extent of cross-sectional dependence. This is specified as follows.

$$CD = \sqrt{\frac{2}{N(N-1)}}\left(\sum_{I=1}^{N-1}\sum_{J=I+1}^{N}(T\hat{\rho}_{ij}^2)\right) \quad (5)$$

Lastly, it is crucial to examine the direction of causality because it helps policymakers formulate affect policy. In order to examine the direction of causality, the study employs the Dumitrescu-Hurlin (DH) (2012) heterogeneous Granger causality method that assumes short-run and long-run causality. According to Azam, Shafique & Yuan (2021), the D.H. has two advantages over other traditional panel causality methods: (i) it can be applied under the situation of T > N and T < N, for unbalanced data and heterogeneous panels; and (ii) considers cross-sectional dependence. Based on the D.H., short-run causality among the series is determined. The long-run causation is analysed by statistical significance of error correction term E.C.T. (−1) obtained from the residual of Equation (2). DH is based on the following linear heterogeneous model:

$$Z_{it} = \beta_i + \sum_{j=1}^{j} \phi_i^j Z_{i,t-j} + \sum_{j=1}^{j} \theta_i^j Y_{i,t-j} + \varphi_{it} \quad (6)$$

where we represent the cross-sectional unit, and t represents time.β_i is the country-specific effect, j refers to the optimum lag interval for all cross-sections, ϕ_i^j assumes the autoregressive coefficients and θ_i^j is the regression parameter allowed to vary among the groupsφ_{it}, is the vector of error terms y and z represent the series in which causality will be assessed.

3.1. Data

This study used panel data of 8 OPEC countries and 9 high industrialised countries from 1985 to 2020. The selected time scope and country scope is premised on data availability. The variables adopted in this study are foreign direct investment which is a type of investment made by a company or individual from one country into another country. FDI can take the form of buying an existing business, expanding operations of an existing business, or starting a new business from scratch. FDI is often viewed as an important source of capital, technology, and expertise for host countries, and can also have positive spill over effects on the local economy. Industrial output which is another independent variable measures the total value of goods produced by industries within a given period of time. Industrial output is an important economic indicator because it reflects the level of activity in the industrial sector, also real gross domestic product per capita measures the total value of goods and services produced in an economy at constant basic prices divided by the number of people in that country. It measures the relative performance of a country. Energy consumption is another control variable which refers to the amount of energy used by a system, organisation, or individual to power their activities. The independent variable is CO_2 emissions which refers to the release of carbon dioxide gas into the atmosphere as a result of human activities, primarily the burning of fossil fuels such as coal, oil, and gas. CO_2 emissions contribute to global climate change by trapping heat in the Earth's atmosphere and causing the planet's temperature to rise. The data was sourced from the World Development Indicator database, OECD database, and World Energy Balance database.

4. Result and discussion

We began the analysis by first examining the extent of cross-sectional dependence in the series. We, therefore, ignore the result of the CD test and perform the first-generation unit test, and afterward, we proceed to the second-generation unit test. Both the first and second-generation panel unit root was employed in order to give more robust information about the unit root process in the series. Table 1 and Table 2 depict the CD test result and the first and second-generation unit root test results for the two-panel samples. From Table 1, it is evidence that the variables for the OPEC countries have cross-sectional dependence. That is, carbon emission (CO_2E), foreign direct investment (FDI), economic growth (GDP), and the interaction of Industrialization and energy consumption (IVA*EC) have a strong cross-sectional dependence. All the variables except CO_2 have cross-sectional dependence in the highly industrialised (ID) countries. Further, the first and second-generation results show evidence of mixed order of integration for the two samples.

Due to the superiority of the second-generation panel unit root test result over the first generation, in the presence of cross-sectional dependence, we conclude the unit process based on the outcome of the second-generation panel unit root test result. From Table 1, the first-generation unit root test suggests that only FDI is stationary at level while CO_2E, GDP, and IVA*EC becomes stationary after the first difference. Furthermore, the second-generation unit root test suggests that only CO_2E is stationary after the first difference while FDI, GDP, and IVA*EC are stationary at levels. CO_2E is stationary after the first difference, while FDI, GDP, and IVA*EC are stationary at levels for the OPEC sample. From Table 2, following the basis of concluding for OPEC countries, we conclude that FDI is stationary at a level. At the same time, CO_2E, GDP, and IVA*EC became stationary after the first difference for ID countries. Having established the level stationarity of the series, we now proceed to estimate the model with three estimation techniques: the Panel autoregressive distributive lag model (ARDL), the dynamic common correlated effect, and the traditional panel estimation technique. The Panel ARDL (in Table 3) was used to make decisions for OPEC countries, while Dynamic CCE and Static model were used as a robust next check. The Panel ARDL is considered the best because the Pesaran (2004) CD test shows weak cross-sectional dependence. For Table 4, the estimation result of ID countries analysis was based on Dynamic CCE due to the evidence of solid cross-sectional dependence.

4.1. Analysis of the estimated result for OPEC countries

Table 3 is the estimated result for the OPEC countries considered in this study. The pooled mean group informed by the Hausman test is used to estimate the parameters reported for ARDL in Table 3. It can be inferred from Table 3, in the OPEC countries, foreign direct investment (FDI) and economic growth (GDP) have a positive and significant effect on Carbon emission (CO_2E) in the short run and long run, respectively. A 1% increase in FDI and GDP will lead to 1.5% and 167. 5% increase in CO_2E in the short run. In the long run, a 1% increase in FDI and GDP will increase to 16.1% and 22.9%. However, the effect of FDI and GDP on CO_2E is not significant at the 10% level in the short run, but in the long run, FDI and GDP significantly increase CO_2E even at the 1% level of significance.

The interactive effect of energy consumption (EC) and Industrialization (IVA) negatively affects CO_2E in the short run, but the effect is not statistically significant and in the long run as well. The negative short-run effect is not far from the idea that the gain to the environment as a result of Industrialization, which leads to industrial energy consumption, was more than the cost in the short run. Recall that OPEC are developing countries and in most of these countries, non-degradable items like plastic bottles and other materials were used domestically as a source of energy. As a result of Industrialization, it was now borne in people's minds that these materials could be recycled to a more valuable and income-yielding form. Also, Industrialization brought a more modern form of cooking with less carbon emission than the traditional form. As Industrialization continues, the reduction in carbon emission due to an increase in industrial output becomes lower than the carbon emission due to energy consumption during the production process in the long run. However, the IVA*EC has no significant effect on CO_2E both in the long run and in the short run, meaning that policy aims to reduce CO_2E by influencing the interaction of energy consumption (EC) and Industrialization in OPEC will not be effective. Also, the speed at which shock to FDI, GDP, and IVA*EC is corrected to long-run equilibrium is 29.3%. This can be interpreted as evidence of a long-run relationship among the variables in the model.

Table 1. Panel Unit Root test result for OPEC countries.

		1st Generation					2nd Generation				
		LLC		IPS			CADF		CIPS		
Variable	CD-test	LEVEL	1st dff	LEVEL	1st dff	I(d)	LEVEL	1st dff	LEVEL	1st dff	I(d)
$lnco_2e$	1.8*	−0.42	−2.91***	0.39	−7.29***	I(1)	−0.69	−4.54***	−1.81	−5.28***	I(1)
Lnfdi	22.79***	2.19	−1.97**	2.51	−4.73***	I(0)	−2.31**	−	−2.25*	−	I(0)
Lngdp	33.49***	−2.75***	−	0.49	2.53***	I(1)	−5.09***	−	−2.87***	−	I(0)
Lniva*lnec	8.62***	0.59	−5.08***	0.77	−10.60***	I(1)	−5.41***	−	−3.82***	−	I(0)

Source: Authors Compilation.

, **, * denotes significance at 10%, 5% and 1% level respectively.*

Table 2. Panel Unit Root test result for ID countries.

		1st Generation					2nd Generation				
		LLC		IPS			CADF		CIPS		
Variable	CD-test	LEVEL	1st dff	LEVEL	1st dff	I(d)	LEVEL	1st dff	LEVEL	1st dff	I(d)
$lnco_2e$	−1.6	−1.60*	−1.72**	0.98	−7.37***	I(1)	2.59	4.54***	−1.02***	−5.08***	I(1)
Lnfdi	4.45***	−2.61**	−	−4.37***	−	I(0)	−3.80***	−	−3.87***	−	I(0)
Lngdp	35.29***	−4.40***	−	1.66**	−	I(0)	−0.62	−6.71***	−1.85	−5.00***	I(1)
Lniva*lnec	6.13***	−3.60***	−	−1.94**	−	I(0)	1.56	−5.41***	−0.97	−4.47***	I(1)

Source: Authors Compilation

, **, * denotes significance at 10%, 5% and 1% level respectively.*

Table 3. Estimation results for OPEC countries.

Variable	ARDL Model	Dynamic CCE	Static model
Long-run			
Lnfdi	0.161***	0.042	0.145***
lngdp	0.229***	−0.046	−0.115***
lniva*lnec	0.005	0.008	0.028***
Cb			1.720***
Short-run			
ECT-1	−0.293***	−0.281**	
D.lnfdi	0.015	0.0212	
D.lngdp	1.675	−0.545	
D.lniva*lnec	−0.002	−0.005	
Ca	−1.159***		
Hausman	1.69	1.36	4.44
P-value	0.638	0.715	0.218
Model	PMG	CCEPMG	Random
NT	320	320	328
N	8	8	8
CD		1.59	−1.618

Source: Authors Compilation

NT is number of Observation, N is number of countries, CD is cross sectional depence test, Ca is short run constant term, and Cb is long run constant term. **, **, *** denotes significance at 10%, 5% and 1% level respectively.*

4.2. Analysis of the estimated result for highly industrialised countries

Estimated result for the Industrialised Countries (ID) countries considered in this study are reported in Table 4 is. For ID, the Common Correlated Effect pooled mean grouped (CCEPMG) was employed to estimate the model under consideration. The study employed the CCEPMG to correct the issue of cross-sectional dependence. Also, CCEPMG was favoured by the Hausman test result. It can be inferred from Table 4 that foreign direct investment (FDI), economic growth (GDP) and interactive effect of energy consumption (EC) and Industrialization (IVA) have a positive effect and neon Carbon emission (CO_2E) in the long run respectively. FDI has a negative effect on (CO_2E) in the short run, while GDP and IVA*EC positively affect CO_2E in the short run. A 1% increase in FDI, GDP, and IVA*EC will lead to a 0.1%, 0.8%, and 0.5% increase in CO_2E in the long run. In the short run, a 1 % increase in GDP and IVA*EC will lead to a 1.5% and 33.3 % increase in CO_2E, while a 1% increase in FDI will lead to a 0.7% decrease in CO_2E in the short run. However, the long-run effect of FDI, GDP, and IVA*EC on CO_2E appears not significant at the 10% level significance. Still, in the short run, FDI and IVA*EC significantly affect CO_2E even at the 5% significance level.

IVA*EC not being statistically significant, in the long run, can be traced to the idea that the industrial countries are developing and are constantly developing technologies that will consume little or no carbon-related energy. The error correction term, which is negative but insignificant, implies no long-run relationship between FDI, GDP IVA*EC, and CO_2E in ID countries. The speed of adjustment, which is 2.3%, is shallow and statistically not significant, which means that adjusting to long-run equilibrium is prolonged and not significant. Intuitively, FDI, GDP IVA*EC, and CO_2E may never converge to a long run time path, given the not significant and small convergence rate.

Table 4. Estimation results for highly industrialised countries.

Variable	ARDL Model	Dynamic CCE	Static Model
Long-run			
Lnfdi	0.083	0.001	0.047***
Lngdp	−0.015	0.008	0.067***
lniva*lnec	0.385	0.005	0.106***
Cb			−2.939***
Shortrun			
ECT	−0.277***	−0.023	
D.lnfdi	−0.006**	−0.007**	
D.lngdp	0.058	0.015	
D.lniva*lnec	0.197***	0.333***	
Ca	−3.676**		
Hausman	6.84	5.6	28
P-value	0.077*	0.133	0
Model	MG	CCEPMG	fixed effect
NT	360	360	
N	9	9	9
CD		2.41**	0.588

Source: Authors Compilation

NT is number of Observation, N is nuberm of countries, CD is cross sectional depence test, Ca is short run constant term, and Cb is long run constant term. **, **, *** denotes significance at 10%, 5% and 1% level respectively.*

4.3. Panel causality

Table 5 and Table 6 depicts the outcome of the short-run causality relationship among the variables of interest in OPEC and ID countries, respectively. Considering OPEC countries, Bidirectional causality exists between Industrialization (IVA) and carbon emission (CO_2E), as well as IVA and energy consumption (EC). A Unidirectional causality exists between EC and CO_2E. The existence of bidirectional causality between IVA and EC and IVA and CO_2E is evidence of an endogenous relationship between IVA, EC, and CO_2E. Changes in either of the variable will necessitate changes in others. The interaction of energy consumption and Industrialization (IVE*EC) have no causal relationship with CO_2E. The nonexistence of a causal relationship between IVE*EC and CO_2E further reaffirms the PMG result report in Table 3, that the IVE*EC has no significant effect on CO_2E in the short run.

It can be inferred from Table 6 that a unidirectional causality exists between IVE*EC and CO_2E in ID countries. Meaning that CO_2E does cause them to interact, but the interaction of IVE and EC causes changes in CO_2E. There is bidirectional causality between IVE and EC; IVE and CO_2E; CO_2E and EC.

Table 5. Dumitrescu-Hurlin Granger Causality for OPEC countries.

Null Hypothesis	Zbar-Stat.	Decision
LNIVA does not homogeneously cause $LNCO_2E$	2.680***	Bidirectional causality
$LNCO_2E$ does not homogeneously cause LNIVA	6.259***	
LNEC does not homogeneously cause $LNCO_2E$	4.641***	Unidirectional causality
$LNCO_2E$ does not homogeneously cause LNEC	−0.865	
LNIVA*LNEC does not homogeneously cause $LNCO_2E$	0.429	No Causality
$LNCO_2E$ does not homogeneously cause LNIVA*LNEC	1.73	
LNEC does not homogeneously cause LNIVA	7.255***	Bidirectional causality
LNIVA does not homogeneously cause LNEC	6.434***	

Source: Authors Compilation

*, **, *** *denotes significance at 10%, 5% and 1% level respectively*.

Table 6. Dumitrescu-Hurlin Granger Causality for ID countries.

Null Hypothesis	Zbar-Stat.	Decision
$LNCO_2E$ does not homogeneously cause LNIVA*LNEC	0.440	Unidirectional causality
LNIVA*LNEC does not homogeneously cause $LNCO_2E$	5.662***	
LNEC does not homogeneously cause LNIVA	3.982**	Bidirectional causality
LNIVA does not homogeneously cause LNEC	4.829***	
$LNCO_2E$ does not homogeneously cause LNIVA	6.885***	Bidirectional causality
LNIVA does not homogeneously cause $LNCO_2E$	6.029***	
$lnco_2e$ does not homogeneously cause LNEC	3.318***	Bidirectional causality
LNEC does not homogeneously cause $LNCO_2E$	7.657***	

Source: Authors Compilation

*, **, *** *denotes significance at 10%, 5% and 1% level respectively*.

4.4. Discussion of result

From the estimated model, it is apparent that the stages of industrialization of a country or group of countries can explain why energy consumption cannot give rise to carbon emission. In the model of OPEC, our findings are consistent with the findings of Danmaraya et al. (2021), who found a negative relationship between industrialization and carbon emissions in OPEC using a dynamic panel data approach. Our study also has such a relationship. However, it is apparent in our study that energy consumption and industrialization does not significantly affect carbon emission, negatively both in the short run and long run in OPEC. That is, policy makers cannot depend on influencing energy consumption and industrialization to reduce carbon emission. It is also clear in the estimate that FDI and GDP are the major long run drivers of Carbon emission in OPEC countries. From the causality analysis, Table 5 supports the result in Table 3, which implies that energy consumed during industrial activity in OPEC is not enough to cause carbon emission. That is, as mentioned earlier, though energy consumption causes carbon emission, the gain from industrialization (in OPEC) offset the positive effect of energy consumption on carbon emission.

Furthermore, in the estimate model of Highly Industrialised countries, contrary to the findings in the estimate for OPEC, we found that the interaction of energy consumption and industrialization affect carbon emission positively. It is clear from the model that the interaction of energy consumption and industrialization on carbon emission is significant in only a short run. It is important that our findings for Highly Industrialised countries are consistent with the findings of existing literature (see, Li et al., 2019; Samreen and Majeed (2020), Wang et al., 2018; Yaseen et al., 2020). From the forging, concluding that the energy consumption through the industrialization of Highly Industrialised countries is the major driver of carbon emission in the world is not out of place. This finding is further validated by causality results. From the causality result in table 6, it is clear that the interaction of energy consumption and industrialization causes carbon emission, but carbon emission does not cause the interaction of energy consumption and industrialization. This implies that there is a unidirectional causality between the interaction of energy consumption and industrialization and carbon emission.

4.5. Robustness check

In order to test for the robustness of the estimation result for the different samples examined in this study, we estimated the model with three different estimators. The estimated parameter of the different techniques used is the same in most cases. However, the differences observed are due to the superiority of a particular estimator over the other or due ability of a particular estimator to handle a particular estimation problem than the other. For instance, in Table 3, the PMG estimator shows that only lniva*lnec have a negative and insignificant effect on $lnco_2e$ in the short run. In contrast, FDI and GDP have a positive and insignificant effect on CO_2E in the short run.

The CCEPMG, on the other hand, suggests that both lniva*lnec and GDP have a negative effect on CO_2E in the short run, while only FDI has a negative effect. The short-run result was not reported for the Random effect estimator because it is a static Model. We followed the PMG result because of its superiority over CCEPMG in the absence of cross-sectional dependence. The long-run effect of the other variables on CO_2E produced by the three estimators is the same except for the GDP. The Random effect and CCEPMG estimators reported negative while the PMG reported positive. Finally, for Table 4, the negative Long-run effect of GDP produced by the MG estimator was the only difference between the MG estimator and the CCEPMG estimator. We followed the CCEPMG estimator that the effect of GDP on CO_2E is positive because of the evidence of strong cross-sectional dependence, which makes the result of the MG estimator spurious.

5. Conclusions

The primary objective of this study is to determine whether energy consumption due to Industrialization leads to carbon emission in OPEC and highly industrialised countries. Furthermore, the study aims to examine the direction of causality among energy consumption, Industrialization, and carbon emission, and the direction of causality between the interactive effect of energy consumption and Industrialization. We employed both the first and second-generation unit root tests such as LLC, IPS, C.I.P.S., and C.A.D.F. in order to test for the level of stationary of the series. The study also used Pesaran (2004) CD test for cross-section dependence. The PMG estimator was used to estimate the model parameter for OPEC countries, while the CCEPMG was used to estimate the model parameters for highly industrialised countries.

The Dumitrescu-Hurlin Granger causality test is applied to infer the direction of causality. Both the first and second-generation unit root tests suggested a mixed order of integration in the unit root process of the OPEC and ID countries. The PMG result suggests that the interactive effect of Industrialization and energy consumption on carbon emission is negative, but the effect is not significant in OPEC both in the short and long run. Our findings are similar to the findings of Danmaraya et al. (2021) who examined the relationship between industrialization and carbon emissions in OPEC using a dynamic panel data approach and found that industrialization had a negative effect on carbon emissions, indicating that OPEC countries were moving towards more sustainable industrialization practices. However, for highly industrialised countries, the CCEPMG result suggests that the interactive effect of Industrialization and energy consumption has a positive and significant effect on carbon emission in the short run. This consistent with findings of Alam et al. (2021) and Wang et al. (2018) examined the impact of industrialization on carbon emissions in highly industrialised nations using panel data. Finally, the Dumitrescu-Hurlin Granger causality relationship exists among energy consumption, carbon emission, and Industrialization, at least in one direction for both the OPEC and ID countries.

5.1. Policy implication

The policy implication from the conclusion is that policymakers should take into account the differences in the impact of industrialization and energy consumption on carbon emission across different groups of countries. For OPEC countries, the results suggest that policies aimed at reducing carbon emissions may not necessarily focus on limiting industrialization or energy consumption. Which also implies that there may not be a need for immediate policy intervention to reduce carbon emissions through the regulation of energy consumption and industrialization. However, for highly industrialised countries, there is a need for policy measures to reduce carbon emissions resulting from industrialization and energy consumption, particularly in the short term.

The study also suggests that there is a long-term relationship between industrialization, energy consumption, and carbon emission that requires further investigation. Policymakers in highly industrialised countries should focus on sustainable development policies that consider long-term environmental impacts while promoting economic growth. Additionally, the presence of a causal relationship among energy consumption, carbon emission, and industrialization implies that policies aimed at reducing carbon emissions should take a holistic approach that considers the interdependence of these factors. Such policies could include incentivizing the adoption of renewable energy sources, promoting energy-efficient technologies, and implementing regulations on carbon emissions from industrial activities. Overall, these policies should be tailored to the specific context of each country, taking into account the level of industrialization, energy consumption patterns, and other relevant factors.

5.2. Limitation of the study

The major setback of this study is the lack of proxies that accurately and sufficiently capture variables which are supposed to be included in the model in order to make the analysis more robust.

Also, the study considers OPEC countries as a homogeneous group, which may not be accurate given the diversity in their economic structures and energy consumption patterns.

5.3. Link to data source

https://databank.worldbank.org/source/world-development-indicators
https://stats.oecd.org/
https://www.iea.org/data-and-statistics/data-product/world-energy-balances

Conflict of interest

The authors declare no conflict of interest.

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